NITRATE LEACHING RISK ASSESSMENT AFTER INCORPORATION OF FERTILIZED CATCH CROPS

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INTRODUCTION

Stimulating farmers to grow catch crops by increasing N input limits is one of the recurrent measures to reduce the contribution of agriculture to elevated nitrate concentrations in groundwater and surface waters. In some cases, farmers are even allowed to apply a limited N dose to the catch crops themselves, particularly after early harvested preceding crops such as winter cereals. This fertilization stimulates catch crop growth and therefore enhances the yield-related effects of growing catch crops. Uptake of fertilized N by the catch crop is assumed to prevent additional nitrate leaching during autumn and winter. After incorporation of the catch crop in spring, its easily decomposable N is mineralized and is expected to become available for the following crop. However, incorporation of catch crop biomass with a high C:N ratio may initially induce N immobilization, resulting in lower N availability for the following crop. Furthermore, remineralisation of immobilized N might be too late to be still taken up by the crop. For higher catch crop yields due to fertilization, the effect of N immobilization might be more pronounced. Our main research questions for this study were: (1) Are crop yields reduced after incorporation of catch crops with high C:N ratios? (2) Could fertilization of catch crops with high C:N ratios lead to additional nitrate leaching one year after application?

MATERIAL AND METHODS

Incubation experiment

Aboveground biomass of white mustard (WM), Italian ryegrass (IR), black oat (BO) and a grass-clover mixture (GC) was collected on a field in Belgium in January 2012. Fresh yields were weighed and subsamples were taken to determine dry matter (DM) yield and C and N content. Subsamples were first dried at 60°C for 3 days. C and N content were then determined with a CN analyzer. Residual moisture content was determined by drying for 12 hours at 105°C in order to obtain DM yield. Catch crops were cut in small pieces of about 0.5 cm^2 and incorporated according to their yields in a sandy loam and a silt loam soil. The soil was brought at a bulk density of 1.4 g cm^{-3} and maintained at a water filled pore space of 50%. Samples were incubated at 15°C for 98 days and every 2 weeks, some samples were destructed. Soil mineral N content (SMN) was determined with a continuous flow analyzer after extraction in a 1:5 soil:solution ratio with 1 M KCl. Microbial biomass carbon (MBC) was determined at day 0, 28 and 98 according to the chloroform fumigation method (Voroney et al., 1993).

Field experiment

Maize (Zea mays) was sown on a sandy loam soil in Belgium on May 1st 2013 and received a pig slurry fertilization of 133 kg total N ha^{-1} topped up with 30 kg N ha^{-1} of NH_4NO_3. The strip-plot experimental design with four replications consisted of two catch crop species incorporated to the soil in early spring: WM and BO, which had both demonstrated N immobilization in the incubation experiment. These catch crops were sown after winter barley on two different dates: August 1st and 30th 2012. Catch crops had received a pig slurry application at sowing at rates of 57 and 114 kg total N ha^{-1}. Fallow treatments and non-fertilized catch crops were included. DM yield and C and N content of aboveground parts of WM and BO were determined as described for the incubation. Maize development was assessed 64 days after sowing by measuring maize plant height and the number of fully developed leaves for ten randomly chosen plants per plot. Fully developed leaves were determined according to the leaf collar method (Abendroth et al., 2011). The plant height was measured from the base up to where the last fully developed leaf was connected to the stem. Maize grain yield was determined 181 days after sowing by harvesting 4 randomly chosen rows per plot, corresponding to an area of 4.5 m^2. Maize grain yield was only determined on plots incorporated with early sown catch crops and on fallow plots. Soil samples were taken before catch crop incorporation in April, in July, in September and in November at 0-30, 30-60 and 60-90 cm and analyzed for SMN. Microbial biomass carbon (MBC) was determined on the 0-30 cm soil samples in September. Both SMN and MBC were determined as described for the incubation.

RESULTS AND DISCUSSION

Incubation experiment

The relative amount of N mineralized after 3 months was in the order GC > IR > WM > BO and was negatively correlated with the C:N ratio of the catch crops (respectively 17, 20, 34 and 40). N mineralization was for each catch crop higher on sandy loam than on silt loam. N immobilization was prominent and long lasting for BO, which was supported by a significantly higher MBC than for the bare soil treatment throughout the incubation period.

Field experiment

C:N ratio of catch crops in spring 2013 differed from the incubated samples collected in 2012: it was 33 to 42 for WM and 17 to 20 for BO, indicating that N immobilization under maize would probably be more prominent on plots incorporated with WM than on plots incorporated with BO.

Before incorporation in April, SMN over the total sampling depth was significantly higher on plots under WM and BO than on fallow plots and it was positively correlated with fertilization. These effects on SMN were clearly observed at all depths under late sown catch crops, while under early sown catch crops, they were only prominent in the 60-90 cm layer. Total SMN was each time higher under late sown catch crops than under early sown catch crops.

In July, no significant differences were observed in SMN. The number of maize leaves ranged from 5 to 6 and was equal for all treatments. However, maize plants were significantly taller on plots incorporated with BO (13.7 cm) compared to plots incorporated with WM (12.4 cm) and fallow plots (12.5 cm), confirming that N immobilization may have been stronger on plots incorporated with WM. There was no effect of catch crop fertilization or sowing date.

In September, total SMN was equal for all treatments. Only in the 60-90 cm layer we did observe a significantly higher SMN on fallow plots than on plots incorporated with catch crops, while on fallow plots SMN was also positively correlated with fertilization. At the onset of autumn, this indicates a higher nitrate leaching potential on fallow plots. MBC in the 0-30 cm layer was significantly higher on plots incorporated with WM (59 mg kg^{-1} dry soil) and BO (56 mg kg^{-1} dry soil) than on fallow plots (51 mg kg^{-1} dry soil), but only for late sown catch crops. Maize development was not assessed in September.

In November, no significant differences were observed in SMN. Maize grain yields were only significantly different between plots incorporated with fertilized BO (10.2 Mg DM ha^{-1}) and fallow plots that had received the highest fertilization dose (11.5 Mg DM ha^{-1}). This result was contradicting with the results for plant height in July.

CONCLUSION

An incubation experiment demonstrated N immobilization for WM and BO incorporated in soil, but this was less clear in the field. Compared to fallow soil, incorporation of BO had a beneficial effect on the maize plant height in early summer, even though this was not reflected in the final yield. As incorporation of BO and WM resulted only in a small increase in MBC (5-8 mg C kg^{-1} dry soil) in the late summer, and not in a consistent reduction in final maize grain yields, we believe N immobilization did not last long enough to limit N uptake by the maize. It is therefore unlikely that additional nitrate leaching would occur in autumn due to incorporation of fertilized catch crops, under the condition that spring fertilization of the main crop is reduced for the expected N release from the catch crop. Growing catch crops seemed furthermore promising in reducing the risk of nitrate leaching even one year after sowing them.

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